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SUMMARY

This study examined the select endocrine and metabolic responses of Norwegian soldiers performing military field training while living in different shelter conditions in the arctic. A field based group (EXP, n = 17) lived in tents and a garrison group (CON, n = 16) lived in barracks for 10 days while performing similar daily training in cold weather. Cortisol, testosterone, thyroxine, glucose, triglycerides, and beta-hydroxybutyrate were measured on day 1, 5, and 10 of training.

The cortisol and testosterone findings suggest a moderate, but somewhat transient, stress response is associated with field living. The living conditions, however, did not seem to influence the metabolic responses to the physical activity. The observed changes in thyroxine, glucose, and triglycerides (i.e., reductions) suggest that an energy imbalance may accompany arctic military training.

INTRODUCTION

Humans have extensive physiological defenses against heat, but very few and limited coping defenses against cold. In the cold they must rely heavily upon shelter and clothing to supplement and replace the innate physiological temperature regulation mechanisms of the body. That is, a strategy of behavioral temperature regulation is adopted. Many research studies of human responses to cold have been laboratory based where variables such as exposure duration, activity level, and clothing were rigidly controlled. Considerable extrapolation is required to apply these results to the field working conditions of cold regions because the natural thermal environments are complex and unstable, and individuals are free to modify their behavior to achieve comfort (i.e., adjust their clothing and activity for comfort) (1).

Military personnel of many nations periodically undergo physical training under an assortment of climatic conditions to improve their military readiness. Typically this military training is of a prolonged nature (i.e., several days). Cold weather exposure is a common environmental condition that is encountered with this training. Prolonged physical training of a military nature and cold exposure each are known to produce perturbations in the normal endocrine and metabolic function of the body (2,3,4,5). However, scanty information is available concerning the physiological consequences of prolonged field-based military training in a setting involving the cold environment encountered in the arctic region of the world. The intent of this study was to add to this limited knowledge base. Our purpose was twofold; 1) to measure select endocrine and metabolic changes to prolonged (10 day) military training in an arctic field setting involving cold exposure; and 2) to determine if shelter selection affected the physiological responses to the cold exposure.

MATERIALS AND METHODS

Subjects. Our subjects were Norwegian military infantry soldiers who were all in good physical condition. All subjects gave informed consent prior to participation in the study. The subjects were divided into two groups. Group 1 (EXP; n = 17) lived in tents in the field; while group 2 (CON; n = 16) lived in a military garrison during the study. Throughout the study both groups carried out similar daily military operations (noted below), were equipped/clothed identically, and consumed the same food ration. Following completion of the study, three subjects were excluded from the CON group due to

methodological complications. Their physical characteristics (mean ± SEM) were as follows: age; EXP = 20.4 ± 0.2 yr, CON = 20.5 ± 0.3 yr, height; EXP = 182.3 ± 1.7 cm, CON = 180.9 ± 1.8 cm; and weight EXP = 79.7 ± 2.0 kg, CON = 76.9 ± 2.0 kg.

Military Operations. The operations consisted of skiing and snowshoe marches, survival training, weapon training, and warfare maneuvers. The training took place in Skjold, Norway (approximately 300 km north of the arctic circle; elevation, 300 - 600 m) during late March, early April. The weather consisted of daily intermittent sunshine and overcast, with occasional blowing snow and temperatures of -20 to +5° C. Additionally, wind chill reductions of another 0 to -10° C occurred frequently.

Blood Sampling & Analysis. Resting blood samples were taken on days 1, 5, and 10 of the study. The time of day for blood sampling was constant for each individual. The samples were obtained via venipuncture, and collected in an environmentally controlled field site (~20 - 25° C). Once collected, blood samples were kept cool (4° C) until centrifugation (2000 x g, 10 min). Separated sera was aliquoted and stored frozen at -50° C until biochemical analysis. This analysis consisted of cortisol, testosterone, thyroxine, glucose, triglycerides, and beta-hydroxybutyrate (BOHB) determinations. All hormones were measured by radioimmunoassay procedures involving single anti-body, solid phase methodology (DPC Inc., Los Angeles, CA). All other blood measures were assayed with standard colorimetric procedures with reagents provided by Sigma Chemical Inc. (St. Louis, MO). Additionally, to assess the hydrational status of the subjects, serum osmolality was measured in all samples with a freeze point depression osmometer (Precision Systems Inc., Sudbury, MA). All biochemical analyses were performed in duplicate determinations.

The blood metabolite and hormones selected were felt to represent those physiological measures most likely to be affected by the experimental manipulation as based upon existing research findings (2,3,4,5).

Statistical Analysis. The data were analyzed with a mixed design (analysis of variance) with between group comparisons on the outcome measures and within person comparisons in the time domain. A Duncan multiple range test was used to determine individual mean differences and the significance level was set at $p \leq 0.05$. All reported values are means ± SEM.

RESULTS

The hormonal changes are depicted in Figures 1 - 3. Cortisol was unchanged in the CON group, but was increased significantly at day 10 from day 1 levels in the EXP group (see Fig. 1). Testosterone was also unchanged in the CON group, while in the EXP group a significant reduction was observed at day 5 from day 1 levels (see Fig. 2). However, by day 10 the testosterone levels of the EXP group were comparable to those found on day 1. No change was observed in the day 1 to 5 thyroxine levels. However, at day 10 a significant reduction in thyroxine occurred in both groups (see Fig. 3).

Table 1 reports the metabolic substrate findings. Glucose was significantly reduced at day 5 in both groups, but day 1 and day 10 levels were comparable, and within normal glycemia ranges. Triglyceride levels for both groups at days 5 and 10 were significantly lower than those found at day 1. Both groups showed a slight, but non-significant, elevation in BOHB by day 10. Also, no significant alterations were found in the serum osmolality for either group (see Table 1).

TABLE 1. Blood metabolic substrate responses of the experimental (EXP) and control (CON) groups during the 10 day military training in the arctic*

Measure	Group	Day 1	Day 5	Day 10
Glucose (mg/dL)	EXP	69.5 ± 4.2	51.8 ± 3.2	77.0 ± 5.3
	CON	69.7 ± 5.4	49.6 ± 5.8	66.9 ± 10.1
Triglycerides (mg/dL)	EXP	199.9 ± 23.5	103.9 ± 13.7	91.7 ± 12.1
	CON	244.2 ± 28.1	168.4 ± 27.8	177.0 ± 25.9
B-Hydroxybutyrate (mg/dL)	EXP	8.9 ± 1.4	10.8 ± 2.2	13.2 ± 3.0
	CON	11.4 ± 2.0	13.8 ± 3.9	12.4 ± 3.2
Osmolality (mOsm/kg)	EXP	292.6 ± 1.5	289.5 ± 0.9	290.9 ± 1.0
	CON	290.8 ± 1.9	291.3 ± 1.4	293.7 ± 1.5

* Means + SEM

DISCUSSION

The intent of our study was to measure the endocrine-metabolic changes to prolonged military field-based training in the arctic during cold exposure, and determine if shelter selections affected the physiological responses to the cold exposure.

The findings of elevated cortisol and reduced testosterone suggest a moderate, but somewhat transient, stress response is associated with living in the field shelter as opposed to living in the garrison (6,7). These findings are for the most part in agreement with previous work which has individually examined physiological responses to comparable military physical training and polar cold exposure (3,4,8). The observed thyroxine reduction may also be stress related; however, other possibilities are altered metabolic clearance or caloric deficiency (3,6,9). The last possibility seems more probable, since it is supported by the glucose and triglyceride findings. That is, the decreased glucose at day 5 may have been due to increased carbohydrate usage, a typical adaptation during the early stages of cold exposure (10). In turn the progressive reductions in triglyceride may represent a shift in the metabolism towards lipid substrate usage, with the reduced levels in the blood being due to increased tissue removal (5, 11). Although not significant, the change in BOHB suggests that an increased lipid metabolism may have been occurring in the subjects. Finally, the return of glucose to normal at day 10 may reflect a stabilization of carbohydrate balance as the body has shifted to lipid as a primary fuel source (11). Obviously this is speculation on our part, however, it is well established that military physical training imposes extreme caloric deficits, and this introduces metabolic alterations (2). Therefore, this hypothesis does present a feasible explanation of our data.

It is interesting that the living conditions did not seem to alter the metabolic substrate responses to the training in the arctic. Why the experimental treatment had an effect on certain of the hormones measured, but none of the metabolic substrates, is uncertain. Possibly if we had extended the duration of the experiment, the hormonal alterations noted would have precipitated detectable metabolism alterations. That is, there may have been insufficient time for the changes to become manifested.

We conclude that military physical training in arctic conditions does significantly alter the endocrine and metabolic status of soldiers. The

alterations noted may be driven by stress reactivity as well as an energy imbalance. Furthermore, the increased cold exposure encountered by living in the field during such training exercises shifts select aspects of the resting endocrine status; however, living conditions do not seem to impact blood metabolic substrate levels within the time frame of this study.

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FIGURE LEGEND

FIGURE 1. The cortisol changes (mean ± SEM) for the experimental (EXP) and control (CON) groups during the 10 days of arctic military training.

FIGURE 2. The testosterone changes (mean ± SEM) for the experimental (EXP) and control (CON) groups during the 10 days of arctic military training.

FIGURE 3. The thyroxine changes (mean ± SEM) for the experimental (EXP) and control (CON) groups during the 10 days of arctic military training.

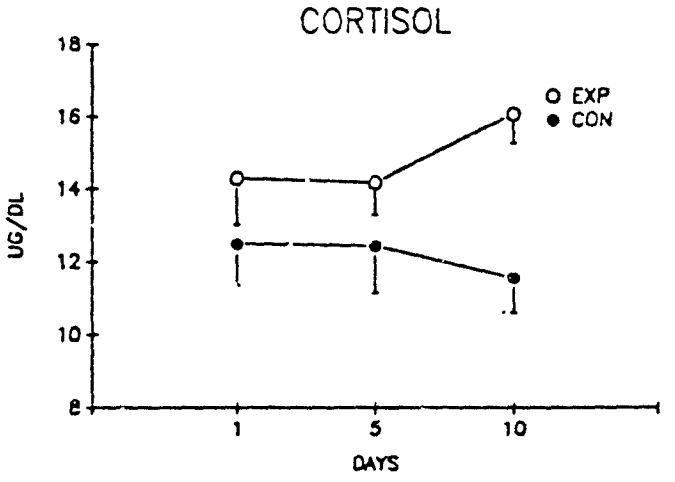

Fig. 1

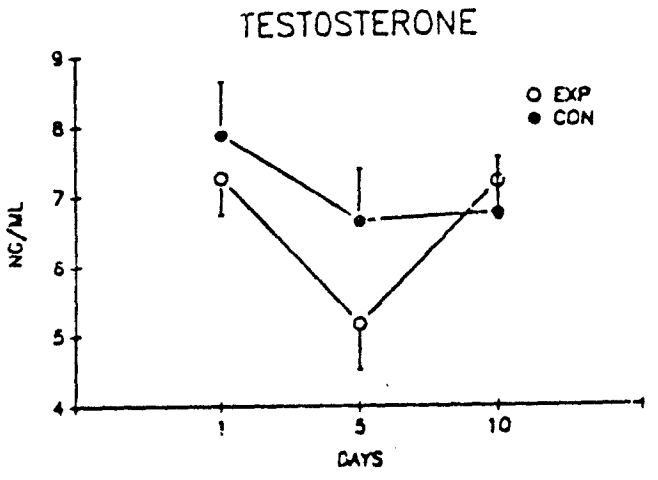

Fig. 2

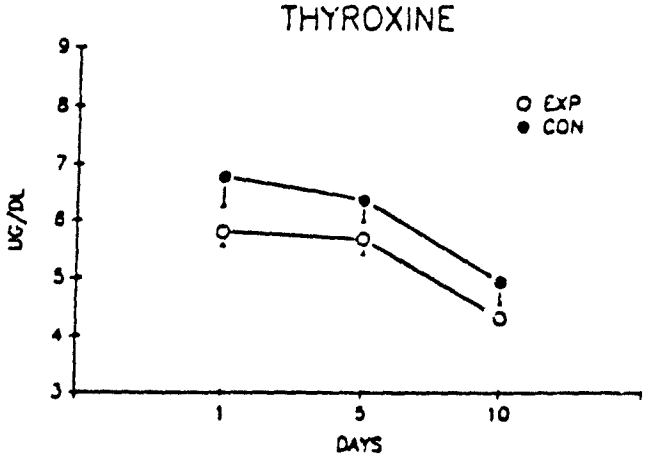

Fig. 3

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